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LLK1694-wind energy resources and development in Iran

Gholamhassan Najafi*, Barat Ghobadian

Tarbiat Modares University, P.O. Box 14115-111, Tehran, Iran

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ABSTRACT

Because of disadvantages of fossil fuels, renewable energy sources are getting importance for sustainable energy development and environmental protection. Among the renewable sources, Iran has high wind energy potential. It has been made clear that the possibilities for wind power in Iran are extremely good. The Iranian government is considerable attention to the utilization of renewable energy, especially wind energy. Due to recent advancements in wind energy, many investors in the country have become interested in investing in this type of energy. At the moment, projects assuming 130 MW of wind power plants are underway, of which, 25 MW was operational in 2004. Based on the planning in the 4th Socioeconomic and Cultural Development Plan (2005–2010), private sector is expected to have a share of at least 270 MW in renewable energies. In 2006, Iran generated 47 MW (Megawatts) of electricity from wind power ranked 30th in the world, this was a 40% increase over 32 MW in 2005. Wind generation was 25 MW in 2004. Wind power plants are in Manjil (Gilan province) and Binaloud (Khorasan Razavi province). Total wind generation from these plants was estimated 128 MW in 2008. Iran had wind power capacity of 130 MWh in 2009 ranked 38th in the world. This study presents a brief introduction to the resource, status and prospect of wind energy in Iran.

Contents

1. Introduction

Renewable energy has the capacity to provide cost-effective energy to remote communities without the added investment of providing fossil generation. Electricity generation is the leading cause of industrial air pollution in the world. Most of electricity comes from coal, nuclear and other non-renewable power plants. Renewable energy sources (solar electric, wind, geothermal, biomass and small and low-impact hydro) can be used to produce electricity with fewer environmental impacts. Renewable energy resources at the end of 2008 have been indicated in Fig. 1. World marketed energy use by fuel type shows that share of renewable energy is increasing rapidly and this trend will continue for the future (Fig. 2). Only 1% of worldwide energy sources depend on renewable energy sources (Fig. 3). Several scientists were studied about status and perspectives of renewable energy sources specially wind energy in different countries [1–21]. The challenge for renewable is great. In case of Iran there is a strong political will to develop the renewable energy resources and harness the potentials. The energy resources investigated and applied in Iran are wind power, solar, thermal, geothermal, photovoltaic, biomass, biogas, hydrogen energy and fuel cell. An assessment of wind energy potential as a power generation source in the capital of Iran, Tehran was done by [22]. Ameri et al. studied on the recent advances in the

* Corresponding author. Tel.: +98 21 48292322; fax: +98 21 48292200.
E-mail addresses: g.najafi@modares.ac.ir, nagafy_14@yahoo.com (G. Najafi).

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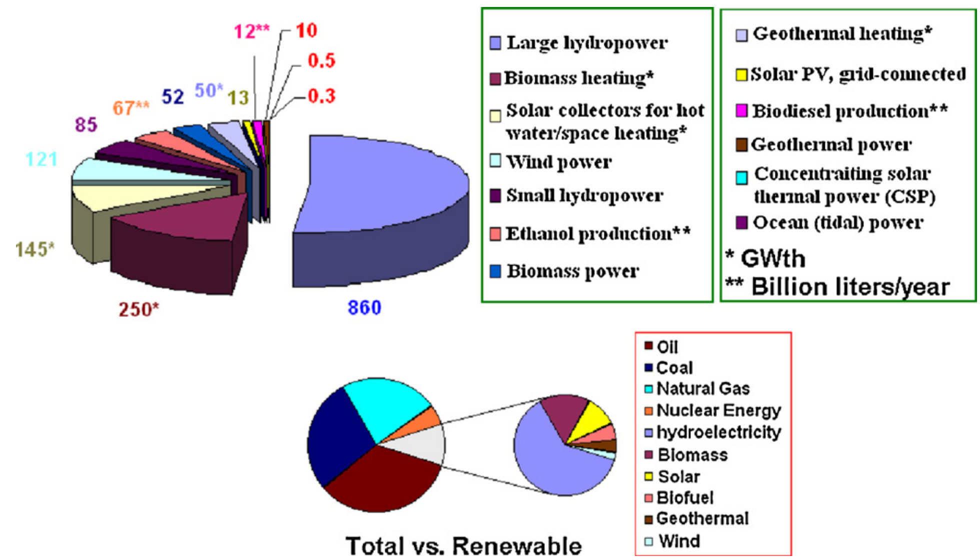


Fig. 1. Renewable energy, end of 2008 (GW) [30,34].

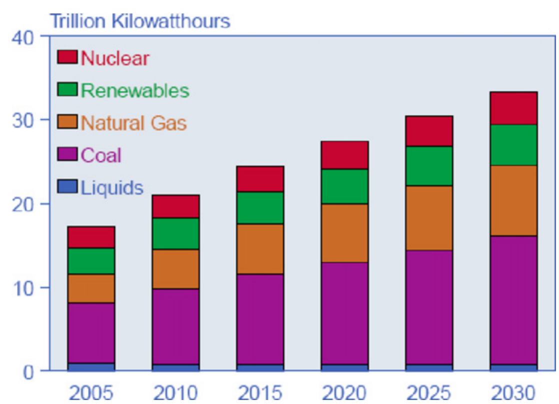


Fig. 2. World marketed energy use by fuel type [30].

implementation of wind energy in Iran [23]. Feasibility study of off-shore wind turbine installation in Iran and harnessing wind energy at Manjil area was studied by [24,25]. Renewable energy in Iran was studied by [26–28]. Fadai studied the feasibility of manufacturing wind turbines in Iran [29].

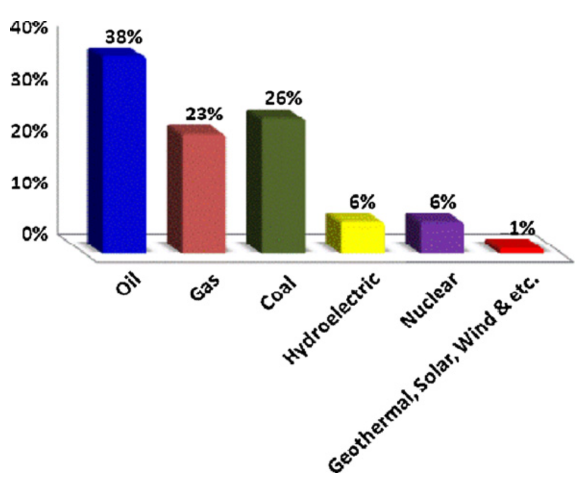


Fig. 3. Worldwide energy sources [31].

2. Iran's energy status

Iran is a member of the Organization of the Petroleum Exporting Countries (OPEC), ranks among the world's top three holders of both proven and natural gas reserves (Figs. 6 and 7). Iran is OPEC's 2nd largest producer and exporter after Saudi Arabia. Natural gas accounts for half of Iran's total domestic energy consumption, while the remaining half is predominately oil consumption. The continued exploration and production of the offshore South Pars natural gas field in the Persian Gulf is a key part of Iran's energy sector development plan [32]. Iran has estimated 137.6 billion barrels of proven oil reserves or roughly 10% of the world's total reserves [33]. In 2008, Iran produced 4.2 million barrels of oil per day (bbl/d) equal to about 5% of global production, Iran exported near 2.4 million bbl/d of oil to Asia and European countries, making it the 4th largest exporter in the world in 2008. Iran's 2009 crude oil production was 3.9 million bbl/d [33]. Fig. 4 shows total energy consumption by type in 2008. Iran's petroleum production and consumption from 1976 till 2008 has been indicated in Fig. 5. Iran's estimated proven natural gas reserves stand at 1,045 trillion cubic feet (Tcf), 2nd only to Russia in 2010. In 2008, Iran produced 4.1 Tcf natural gas and consumed 4.2 Tcf. Natural gas is expected to grow around 7% annually [33].

In 2007, Iran generated 190 billion kilowatt hours (Bkwh) and consumed 153 Bkwh. Nearly 175 Bkwh was generated by conventional thermal electric power, and about 18 Bkwh was generated by hydroelectric power, with a marginal amount of renewable (wind) power provided. Iran's electricity generation and consumption from 1988 till 2007 have been indicated in Fig. 8.

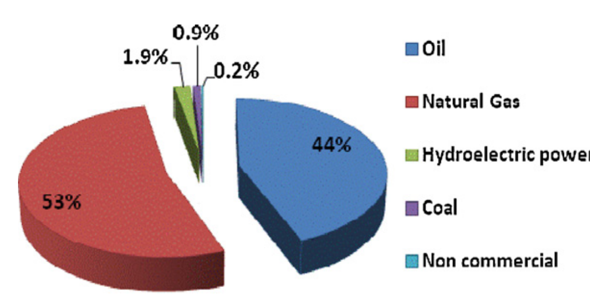


Fig. 4. Total energy consumption in Iran by type (2008) [32–35].

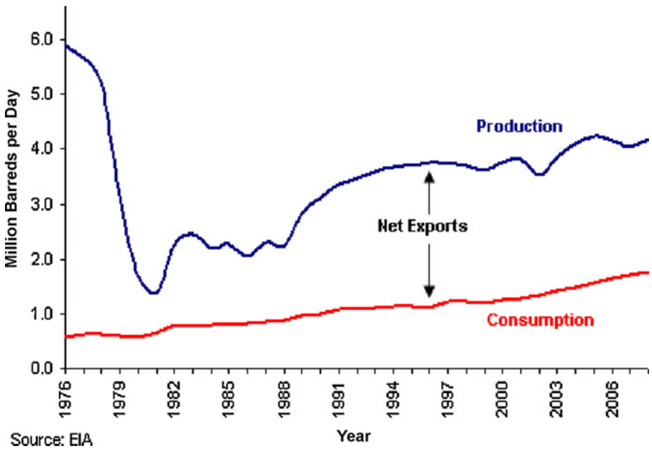


Fig. 5. Iran's petroleum production and consumption 1976–2008 [32–35].

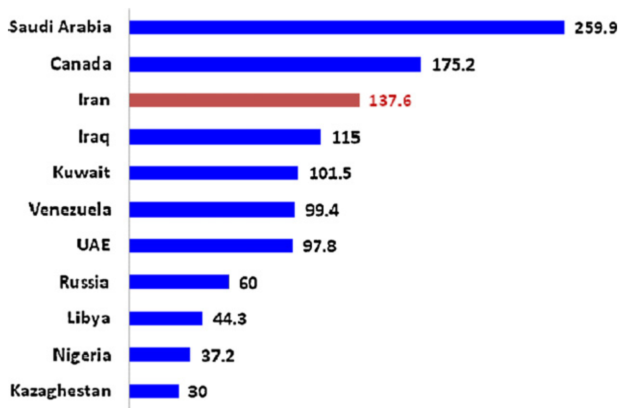


Fig. 6. Top proven world oil reserves (billion barrels), 2010 [32–35].

Iran's nameplate generation capacity is around 49,000 Megawatts (MW), though some plants operate as low as 10% of nameplate capacity. Iran has focused on meeting higher demand mainly through expanding combined cycle and hydro-electric power. The Ministry of Energy estimates that to meet the growth in demand projected, capacity must reach 60,000 MW by 2015 [33–35].

3. Wind energy in the world

The wind sector showed impressive growth rates in the year 2009 (Fig. 9). Increasing awareness of the economic, social and environmental benefits of wind energy will further boost investment in new wind farms. Another positive factor will be the supportive role of International Renewable Energy Agency (IRENA) with 143 member countries. Further growth can especially be expected in the leading wind markets China, USA, Germany, Spain and India and many countries in Europe, Asia and Latin American countries. Based on the accelerated rates, it can be expected to be installed globally 1,900,000 MW by the end of the year 2020 [35]. Wind energy installation by country and Continental shares in new wind capacity has been indicated in Figs. 10 and 11, respectively. As it is

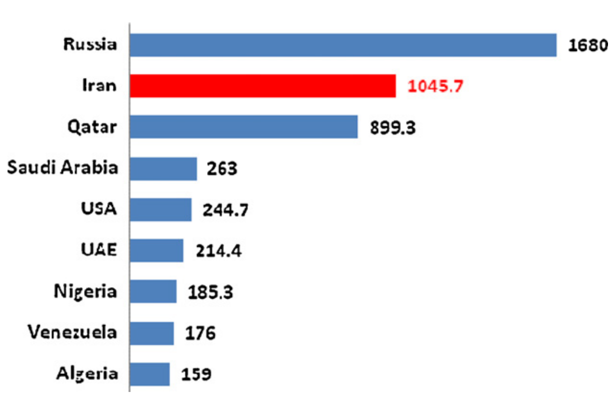


Fig. 7. World natural gas reserves (Trillion cubic feet), 2010 [32–35].

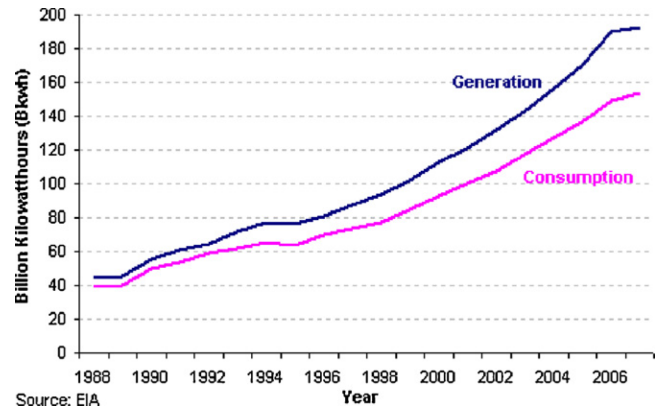


Fig. 8. Iran's electricity generation and consumption, 1988–2007 [32–35].

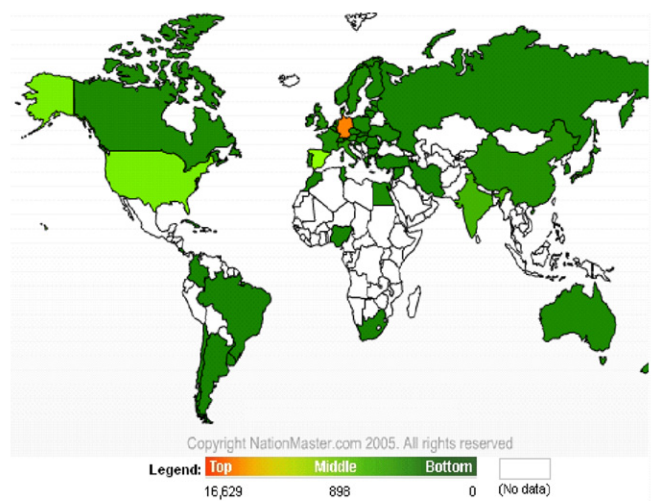


Fig. 9. Wind energy installation by country [36].

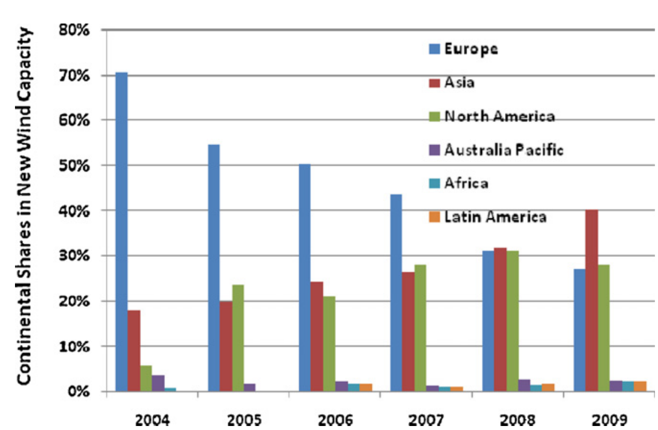


Fig. 10. Continental shares in new wind capacity [34,35].

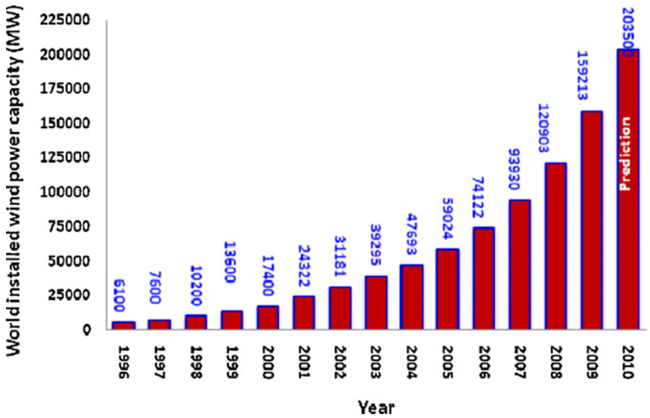


Fig. 11. World installed wind power capacity [34,35].

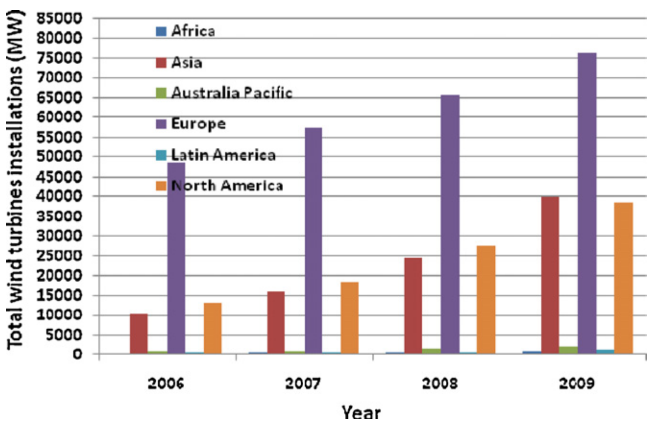


Fig. 12. Total wind turbines installations [34,35].

Table 1
Global installed wind power capacity (MW) [34,35].

Country	Revised end 2006	New 2007	Total end 2007
Africa and Middle East			
Egypt	230	80	310
Morocco	64	60	124
Iran	47	19	67
Tunisia	20	0	20
Other	16	1	17
Total	**378**	**160**	**538**
Asia			
India	6270	1730	8000
China	2604	3449	6050
Japan	1394	139	1538
Taiwan	188	100	282
South Korea	173	18	191
Philippines	25	0	25
Other	5	0	5
Total	10659	5436	16091

clear from this figure, the share of Asia is increasing rapidly. World installed wind power capacity, total wind turbines installations and world electricity generation by fuel were indicated in Figs. 11–13, respectively.

4. Wind energy in Asia and Middle East

Iran is located on Asia continent, in Middle East region (Fig. 14). Iran is the sole center producing wind turbines in the Middle East. 130 MW installed in Africa and Middle East. In North Africa, the expansion of wind power continues in Egypt, Morocco and Tunisia, with 55 MW, 10 MW and 34 MW of new capacity installed, respectively. In the Middle East, Iran installed 17 MW of new capacity. Installed wind power capacity in Africa and Middle East has been showed in Table 1. The total installed wind energy capacity in Africa and the Middle East now stands at 669 MW. There has not been any offshore wind turbine in Middle East yet. There is also potential for offshore wind farms in Persian Gulf, Gulf of Oman, Caspian Sea and Arabian Sea. Future research studies are necessary [24,25,28].

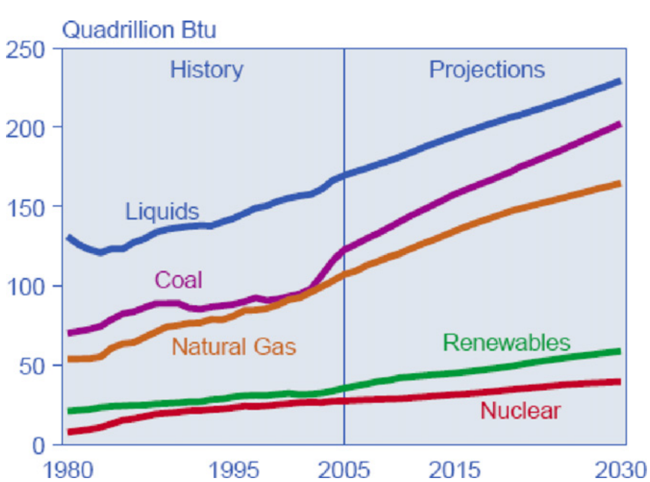


Fig. 13. World electricity generation by fuel [30,31].

5. Wind energy in Iran

Primary energy demand in Iran is projected to increase at an average annual rate of 2.6% in 2003–2030, down from around 5%over the past decade. This assumes that the progressive removal of energy subsidies, now equivalent to a staggering 10% of GDP (gross domestic product). Electricity generation is estimated to be increased from 153 TWh (Terra Watt hour) in 2003 to 359 TWh in 2030, requiring 54 GW of new generating capacity and total investment in power infrastructure of $92 billion [37]. Fig. 15 shows that renewable energy resources do not have wide applications in Iran at present, while the fossil fuels consumption will increase. The use of renewable energy, especially wind energy will make Iran stand for a better chance to have share of energy from non-fossil energy sources, and it will surely decrease the fossil fuel consumption. In Iran, wind energy has great potential to improve energy services [38]. Wind energy will not only be able to contribute to securing Iranian energy independence and climate goals in the future, it could also turn a serious energy supply problem into an opportunity for Iran in the form of commercial benefits, technology research, exports and employment. The economic future of Iran can be planned on the basis of electricity costs that are known and predictable, as this electricity is derived from an indigenous energy source free of the all the security, political, economic and environmental disadvantages associated with oil and gas. Because of the social and economic development in Iran, the demand for energy is growing rapidly. It has been estimated that roughly 10 million MW of energy are continuously available in the earth's wind while the total global installed capacity was 39434 MW in 2004 [39].

The potential capacity of wind power is figured about 6500 MW for the country, mostly in the eastern sections [40]. Considering the good potential of a well situated location, construction of the wind power stations began in 2003 in Iran (the 25 MW and 60 MW power stations at Manjil) reported by Fadai [29,41]. The development of wind powered generators has gotten a deserving attention during the last decade leading to the construction of the country's first such power station [42]. Wind power in Iran has been experiencing



Fig. 14. Location of Iran in Middle East.

a growth in wind generation in recent years. Iran is the sole center producing wind turbines in the Middle East. Total capacity of wind energy for end of 2009 has been indicated in Fig. 16.

At the moment, projects assuming 130 MW of wind power plants are underway, of which, 25 MW was operational in 2004. Based on the planning in the 4th Socioeconomic and Cultural Development Plan (2005–2010), private sector is expected to have a share of at least 270 MW in renewable energies. In 2006, Iran generated 47 MW (Megawatts) of electricity from wind power ranked 30th in the World, this was a 40% increase over 32 MW in 2005.

Wind generation was 25 MW in 2004. Wind power plants are in Manjil (Gilan province) and Binaloud (Khorasan Razavi province). Total wind generation from these plants was estimated 128 MW in 2008. Iran had wind power capacity of 130 MWh in 2009 ranked 38th in the world.

In Iran, further to policies made by the Ministry of Energy's deputy directorate for energy, Iran Renewable Energy Organization (SUNA) has been attending to this matter since 1995 in order to achieve updates information and technology in connection with utilization of renewable energy resource, measurement of potentials and execution of various projects (solar, wind and geothermal, hydrogen and biomass).

In 2007, SUNA started a research to simulate the data of wind resource. Their system is used to obtain the wind resource, wind

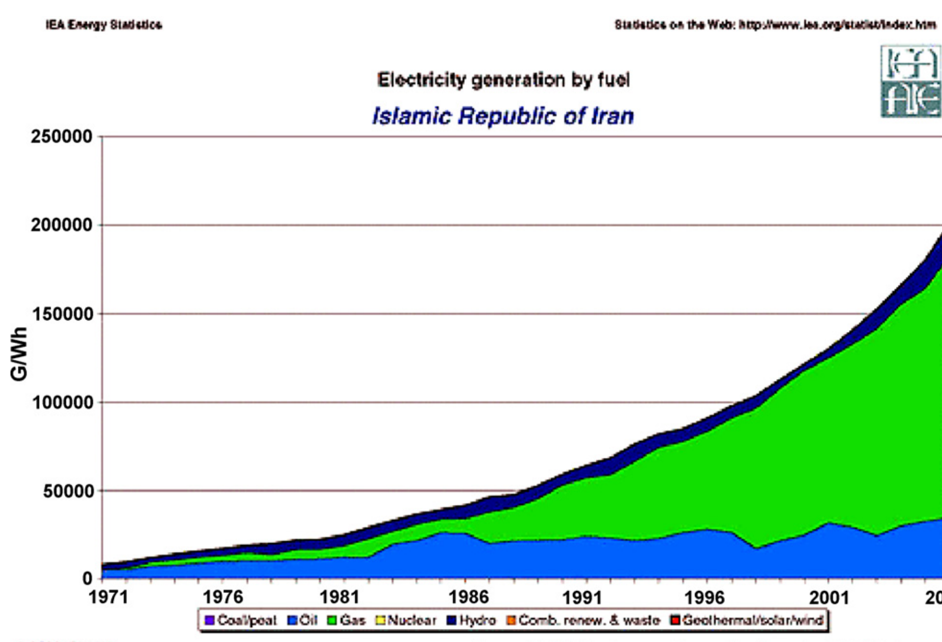


Fig. 15. Electricity generation by fuel for Iran [43,44].

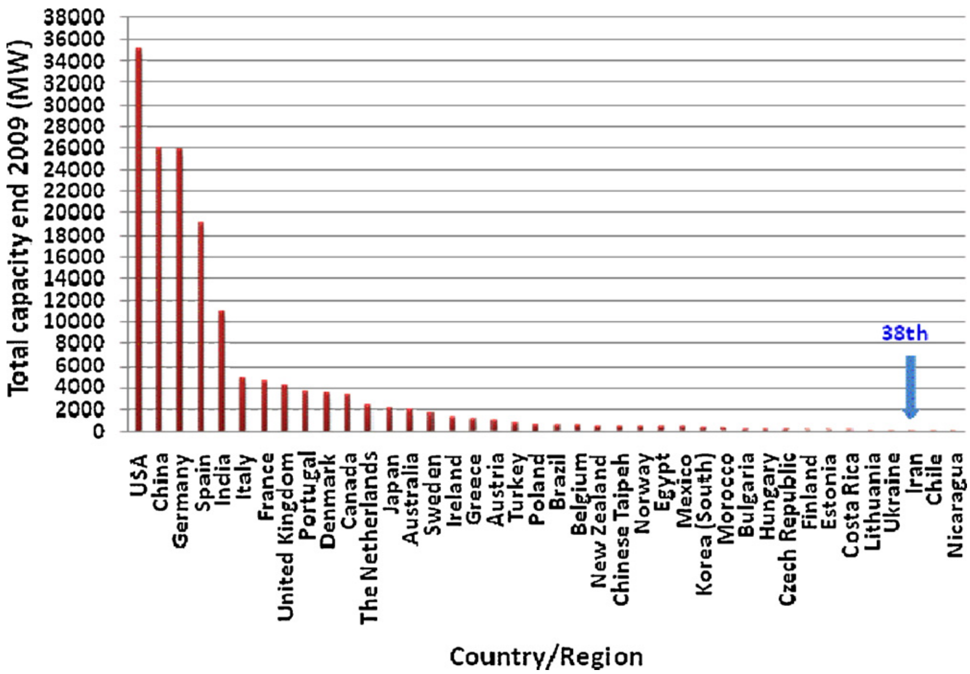


Fig. 16. Total capacity of wind power end 2009 [34,35].

energy and wind speed at a height of 40 m, 60 m and 80 m [45]. Figs. 17 and 18 show the wind energy and the speed of wind at the height of 40 m, respectively. The wind-rich areas are mainly dispersed in north, north-east Iran. Updated draft zero wind map of Iran in 80 m and 50 m above ground has been indicated in Figs. 19 and 20, respectively.

The investigations and the research projects conducted so far to estimate the wind potentials include 26 regions and 45 sites in Iran. The results indicate that though in general the country falls in medium wind velocity regions of the world, but in some of the regions, continuous winds with suitable velocity exists which are capable of generating electricity (Tables 2 and 3). In one of the research projects, a mathematical model was engaged to assess wind energy resources on selected sites potentially suitable for wind energy applications in Iran [46,27]. This research work resulted in estimation of the average yearly energy production of an appropriate wind turbine for 14 selected locations (Bandar-Abbas, Semnan, Zahedan, Sanandaj, Torbat, Heydariye, Ghazvin, Zabol, Kerman, Abadan, Babolsar, Birjand, Rasht, Ardebil and Chabahar). Situation of wind power plant projects in several provinces in Iran is indicated in Table 2. Also specifications of wind turbines for various sites are described in Table 3. Table 4 shows elec-

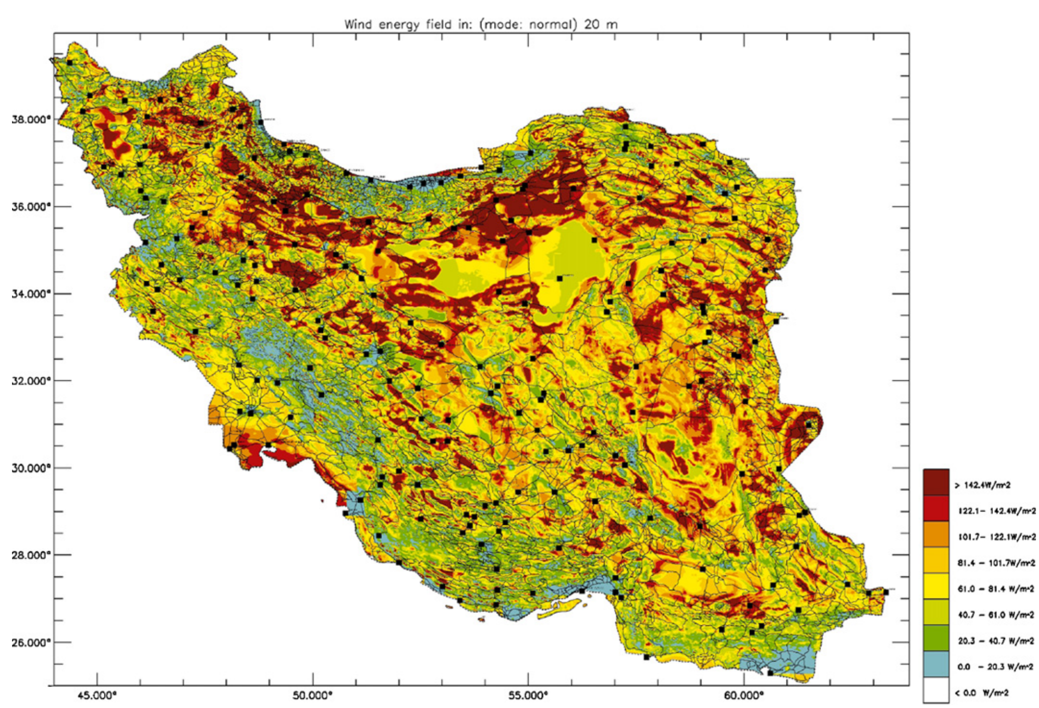


Fig. 17. Wind energy field [44,45].

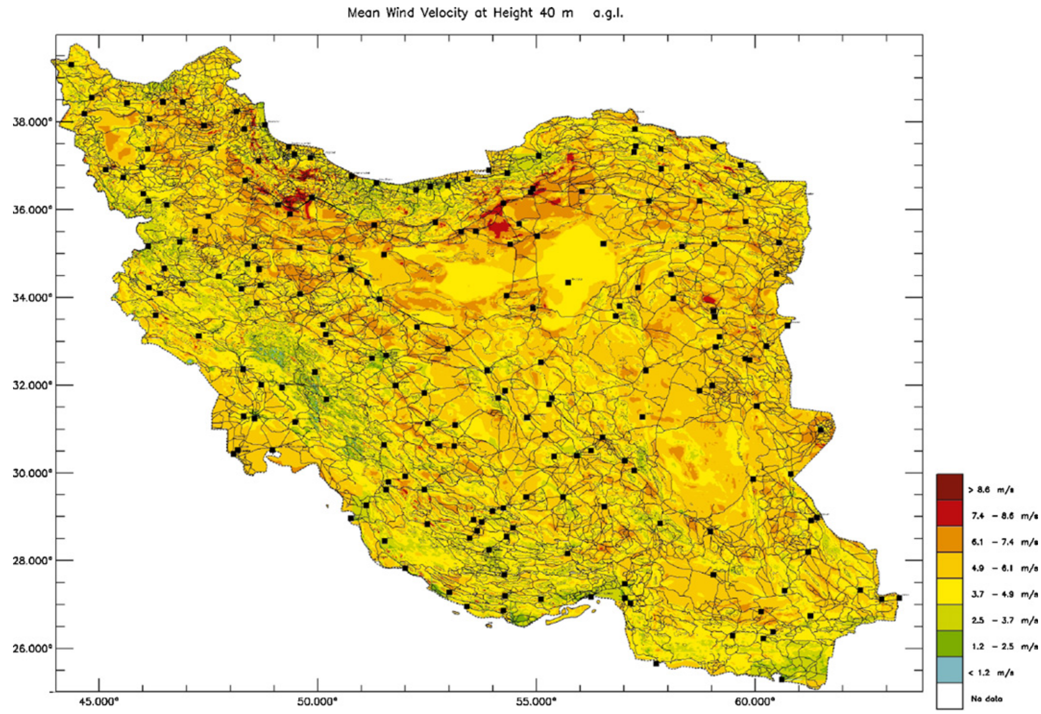


Fig. 18. Mean wind velocity at height 40 m [44,45].

Table 2
Situation of wind power plant projects in several provinces in Iran, 2006 [27].

Province	Operation Spec.		Executive Spec.	
	No.	Capacity (MW)	No.	Capacity (MW)
Gilan	70	34	1	0.01
Ghazvin	–	–	40	26
Khorasan	22	13	24	15
East Azarb.	–	–	1	0.01
Total	**92**	**47**		

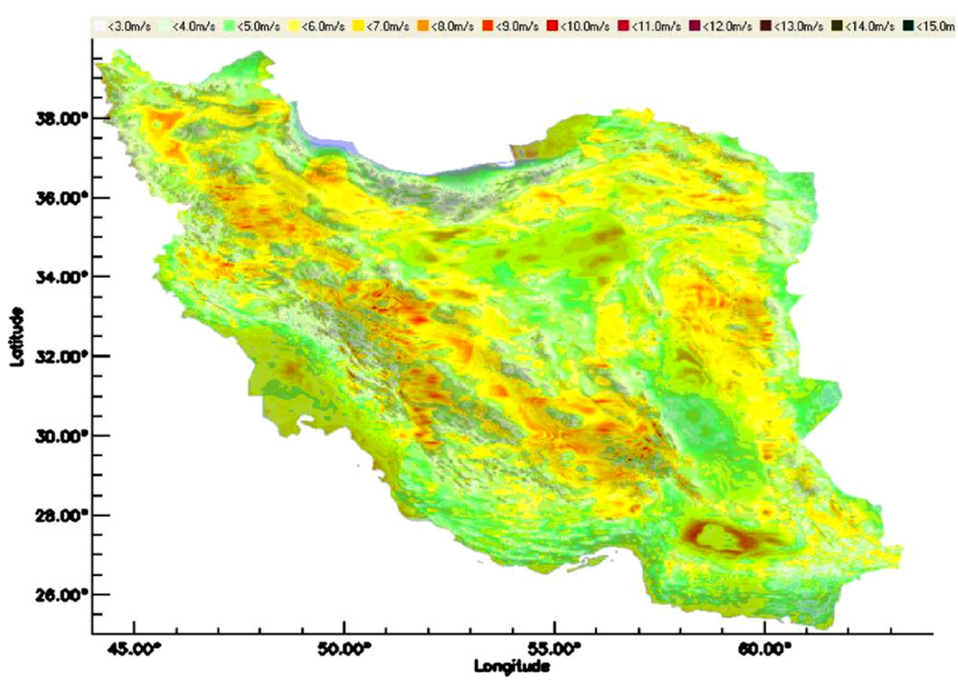


Fig. 19. Draft zero wind map of Iran in 80 m above ground [44,45].

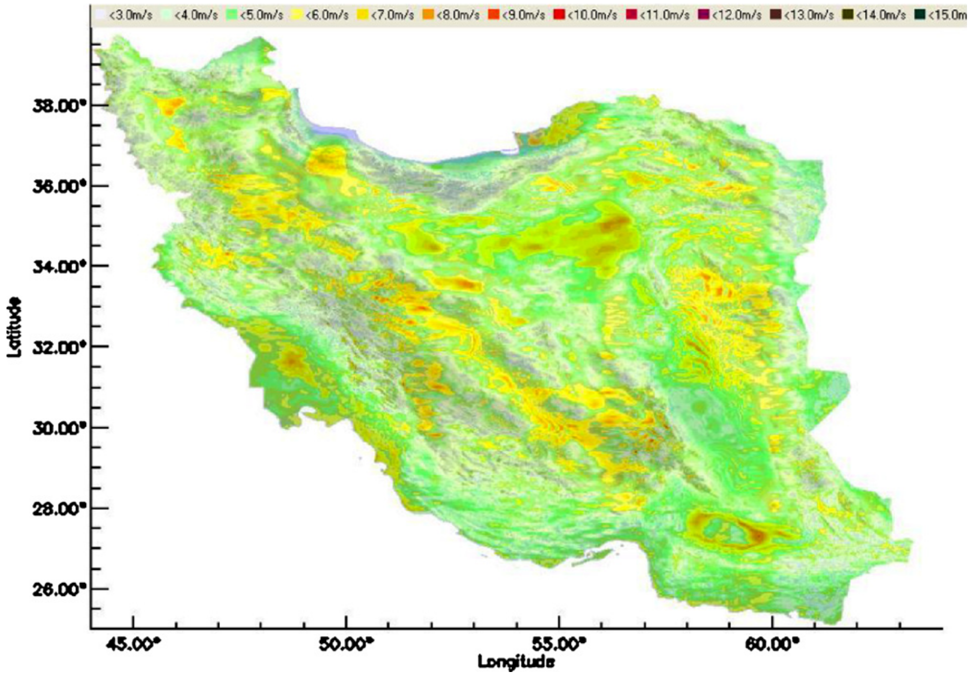


Fig. 20. Draft zero wind map of Iran in 50 m above ground [44,45].

Table 3
Specifications of wind turbines for various sites in Iran [27].

Site	Province	Township	Installed turbines	
			No.	Capacity (MW)
Rudbar	Gilan	Rudbar	4	2.15
Manjil	Gilan	Manjil	31	13.25
Paskulan	Gilan	Manjil	22	14.52
Harzvil	Gilan	Manjil	12	3.6
Babaian	Gilan	Manjil	1	0.6
Binalud	Khorasan	Binalud	20	13.2
VentisDizbad	Khorasan	Mashad	2	0.26
Total	–	**–**	**92**	**47.58**

Table 4
Electricity generation from several wind power plants [27].

Year	Nominal capacity (MW)	No. of turbines	Specific production (MWh)
1994	–	2	140
1995	1	2	4000
1996	1	2	4000
1997	1.2	2	4238
1998	3.95	11	6766.805
1999	9	25	17592.693
2000	9.9	28	35044.075
2001	10	28	36541.568
2002	10.8	28	33656.112
2003	11.3	29	30281.306
2004	25	43	27621.023
2005	32	56	46511.471
2006	47	92	70902.196
2007	67	NA	125000
2008	82	NA	143000
2009	91	NA	NA

Table 5
Specifications of observation and executive programs for wind power in Iran [27].

Project.	Region	Utilize	Cap. (MW)	Production of energy every year (GWh)
Turbine Sahand	Azarbayjan	07	0.01	0.25
Binalud power plant	Khorasan	05	28.4	124
Vahidi turbine	Bojnurd	07	0.06	–
Movahed turbine	Gilan	07	0.01	–
Wind power plant	Gilan	09	60	190
Wind turbine	Gilan	07	90	200–330

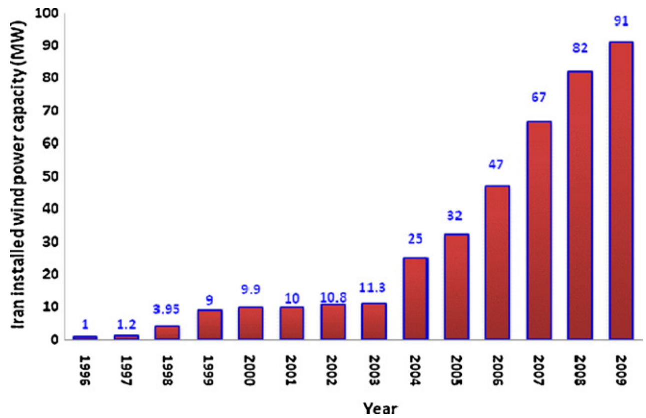


Fig. 21. Iran installed wind power capacity [27,45].

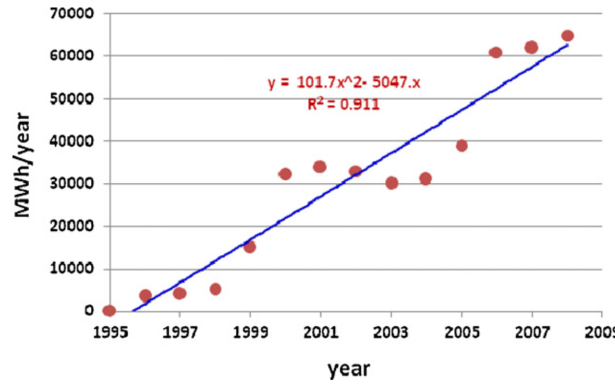


Fig. 24. Electricity generation from Manjil wind power plant [45].

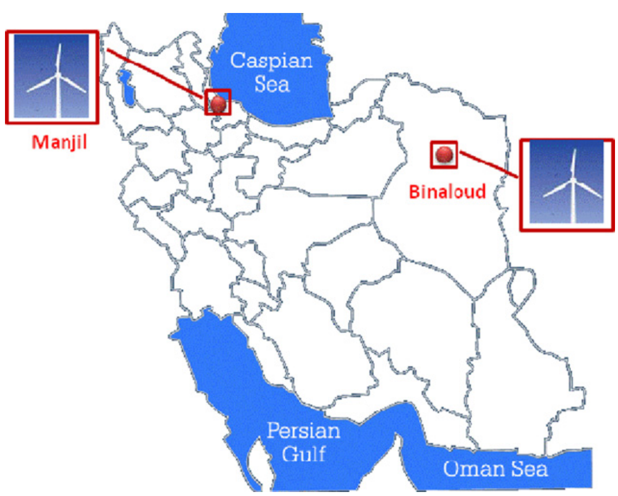


Fig. 22. The geographical situation of Manjil and Binaloud stations [45].

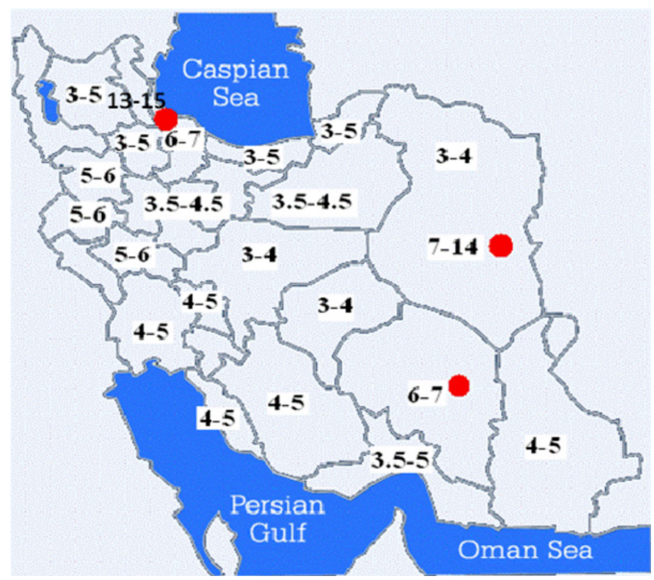


Fig. 25. Variation of wind speed potential in different site in m/s [27,45,46].

tricity production for several sites in Iran from 1997 until 2006 (Fig. 21).

The ministry of energy has serious programs for the evaluation of the wind energy potential in the Iran. At the first stage, the country's wind energy potential evaluation is performed for a wide range of the country. At the second stage, the Iran's wind atlas was prepared. To prepare the wind atlas 53 wind synoptic stations installed all over the Iran. Assessment of these stations indicated that Sefid Rood valley had an excellent wind potential. The Manjil wind site is located at the southeastern part of Sefid Rood Dam and its area is around 2×10^6 m^2. The next large wind farm was commissioned in the Dyzbad at the Binalood mountain which is located in the northeastern part of Iran [23]. The geographical situation of these stations is indicated in Figs. 22–24.

The variations of the wind speed, and the range for each site are depicted in Fig. 25. Meteorological information for the input program is based on 10 years observation (Ahmadi, 1995).

Table 5 shows specifications of observation and executive programs for wind power in Iran.

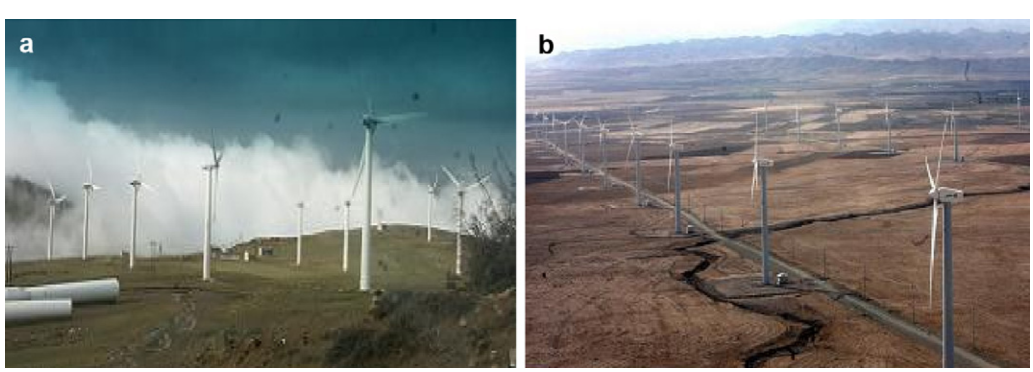


Fig. 23. Wind power plant installed at (a) Manjil and (b) Binaloud [44,45].

6. Conclusion

This paper showed that there is a considerable potential for utilization of wind energy in Iran. Iran has a favourable wind source; the study in this field is not satisfactory much more is needed to be done. Wind energy will play an important role in future energy needs of Iran. The government has projected an installed capacity of about 100,000 MW or 350 BkWh by the 2020. It means that more study and hard work needs to get to this goal. Setting-up international collaborative business venture between Iran Renewable Energy Organization (SUNA) and private renewable energy companies is proposed as an implementation strategy in the country. It is proposed that government protect more from studies in this field and put appropriate policy and strategies for utilization of wind energy. Private sector is expected to have more shares in renewable energies in Iran.

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